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Nanoscale Multilayer Membranes as Optical Elements for EUVL

Presented by L. Sjmaenok

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Outline

- Introduction: potential applications, challenges
- Task: spectral purity filtration
- Task: stopping fast debris particles
- Task: reticle protection
- Conclusions, further steps

Transparent optical elements for EUV could have several critical applications, from spectral purity filtration to optics particle protection.

Necessity to make the optical element extremely thin results in fabrication of free-standing nanometer scale membranes, meeting requirements on heat load, mechanical strength, EUV transmission, handling.

Spectral purity filters to suppress DUV and IR radiation

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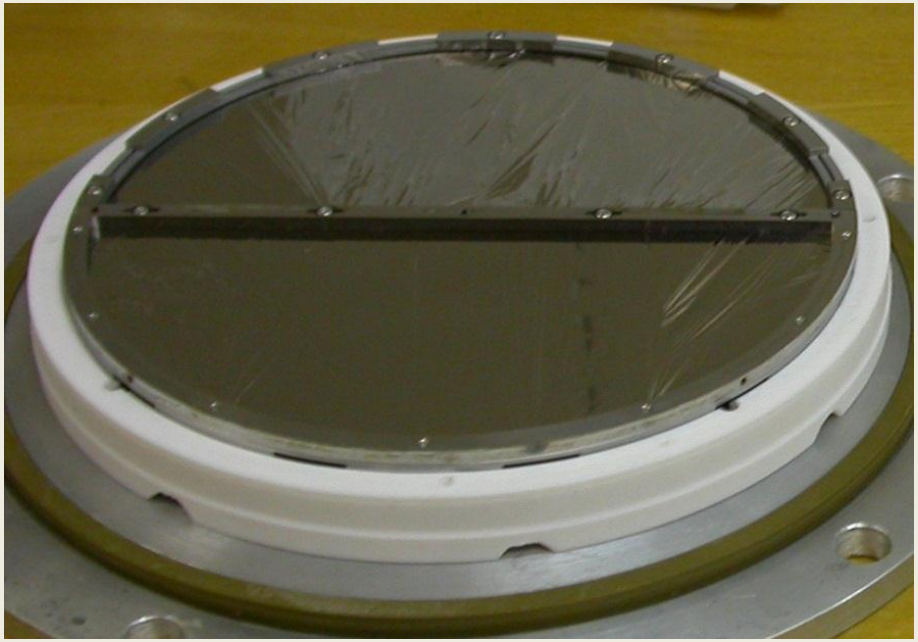
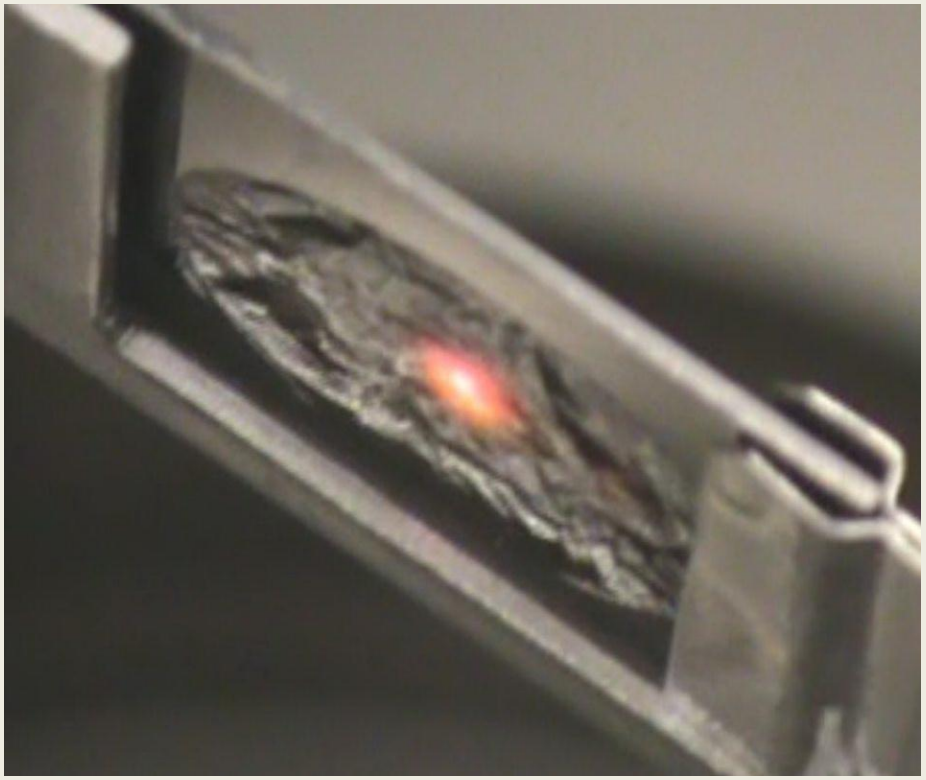
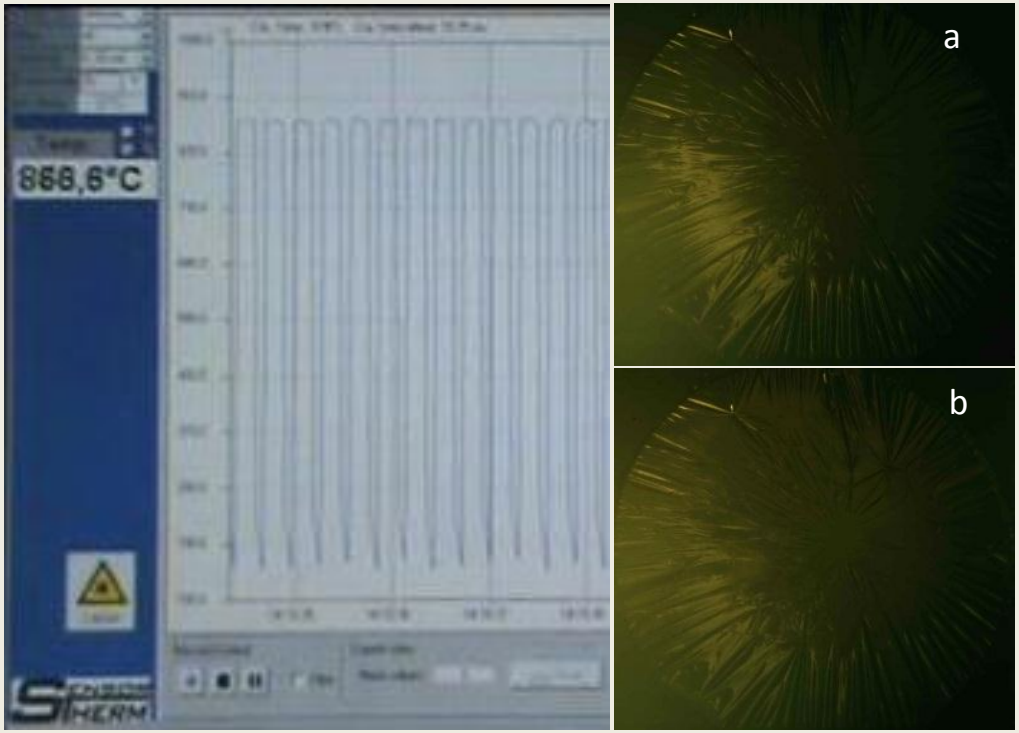
Membranes 52 ÷ 40 nm thick, up to 160 mm in diameter, providing EUV transmission 74-76%, are considered as potential spectral purity filters (SPF) to suppress DUV and 10.6 μm radiation with coefficients $10^2 \div 10^3$. SPFs withstand prolonged heating at absorbed power >5 W/cm^2 and repetitive deformations under modulated power load.



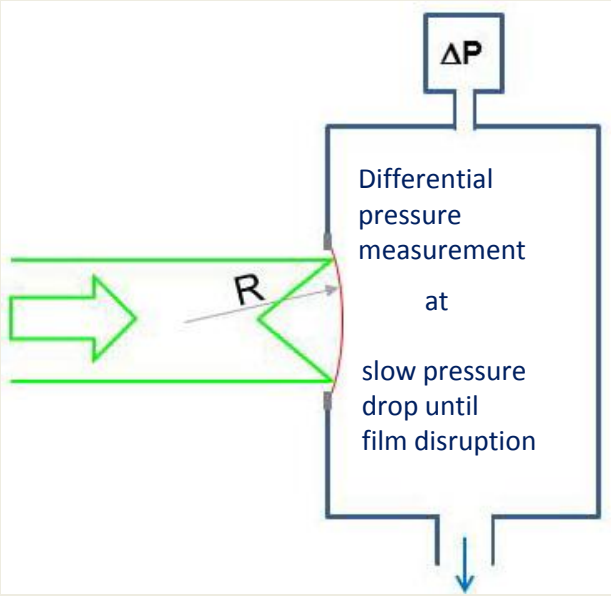
SPF sample with Mo/Zr/Si-based structure, with aperture 160 mm, (two semi-circular parts). Inband transmission 74%, 10.6 μm radiation suppressed by factor >100.

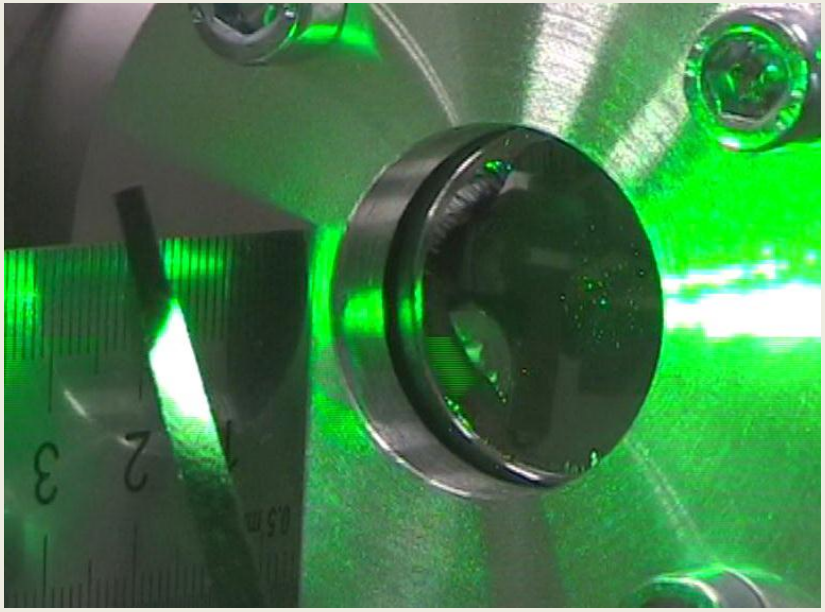


Structural resistance to temperatures up to 1000° C at absorbed power >5 W/cm^2 demonstrated in exposures with duration 100 h



Thermo-mechanical resistance:
after $2*10^6$ temperature modulations (b)
no defects observed with backlight microscopy

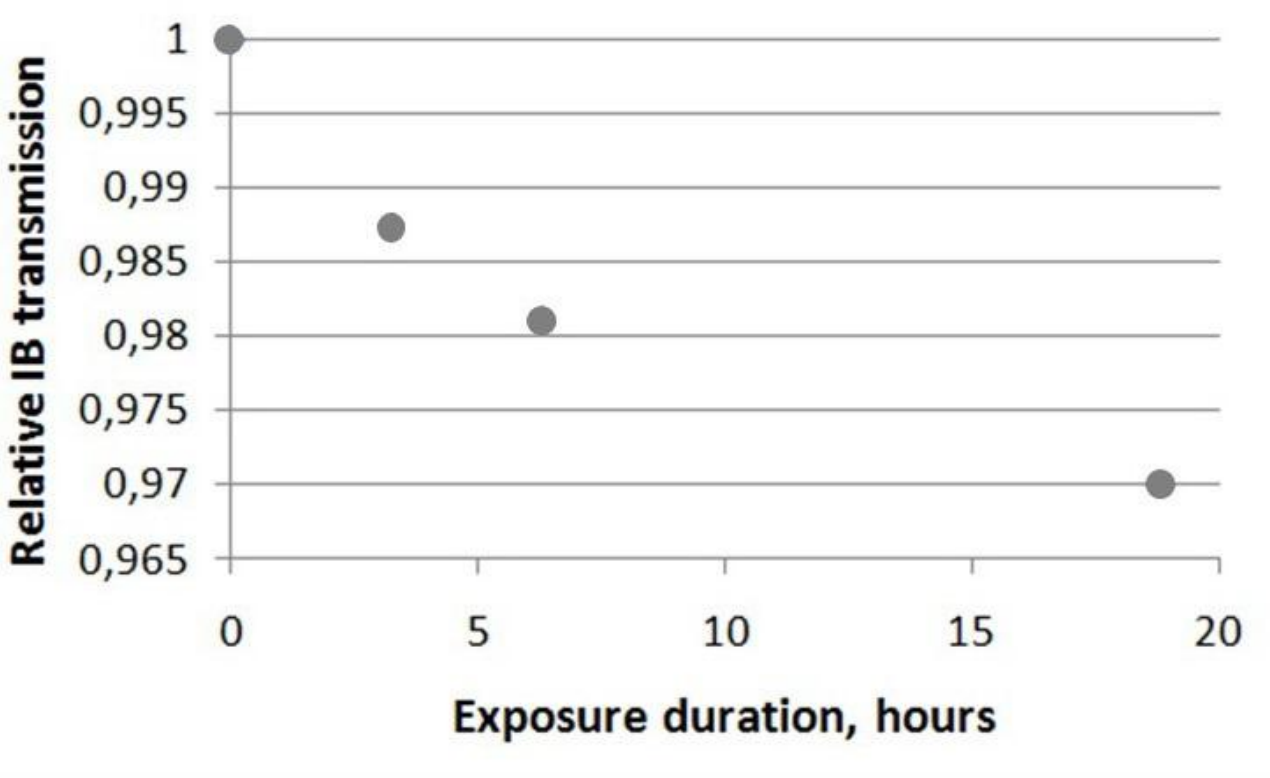




Estimation of film tensile strength from pressure differential and curvature:

$$\sigma = \Delta P \times R / 2h \Longrightarrow 1 \div 2 \text{ GPa}$$

At apertures Ø26 mm $\Delta P \approx 15 \div 35$ mBar

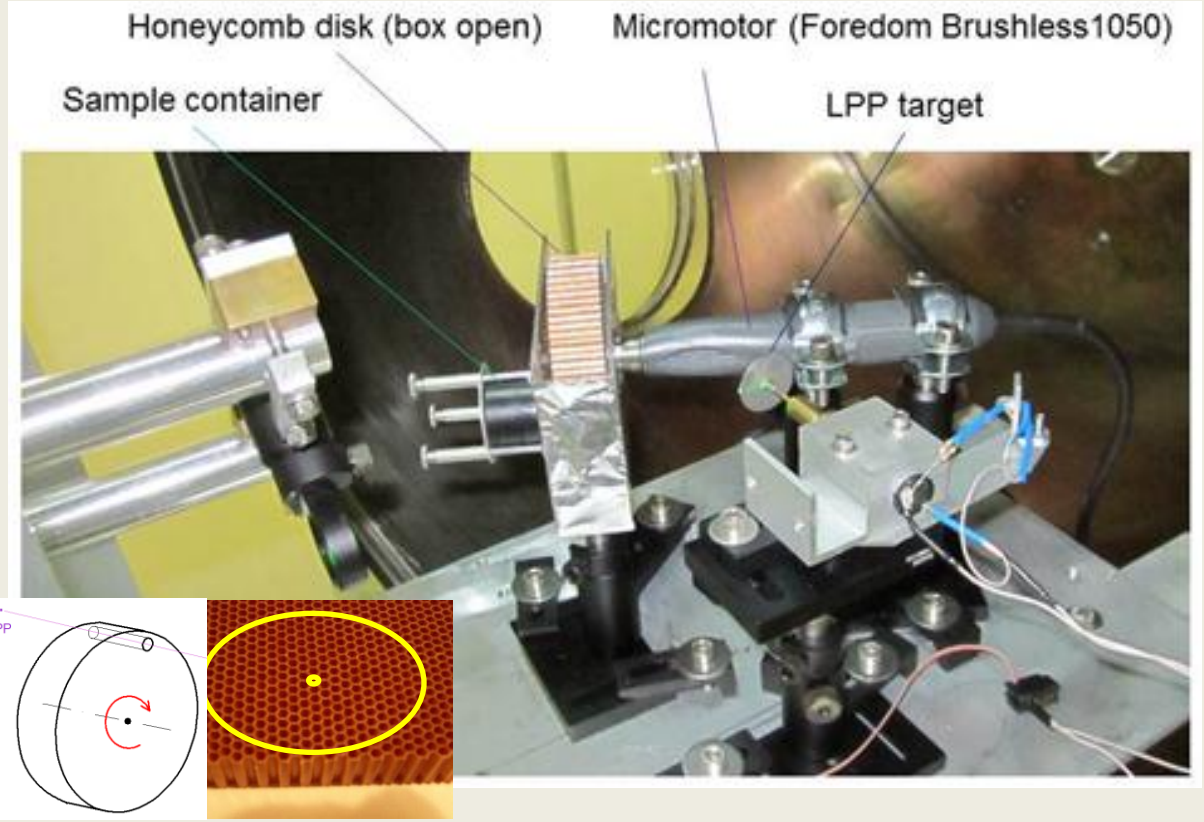


Inband transmission drop of a multilayer SPF membrane annealed at 950 °C (5 W/cm^2), residual H_2O pressure 10^{-7} mbar

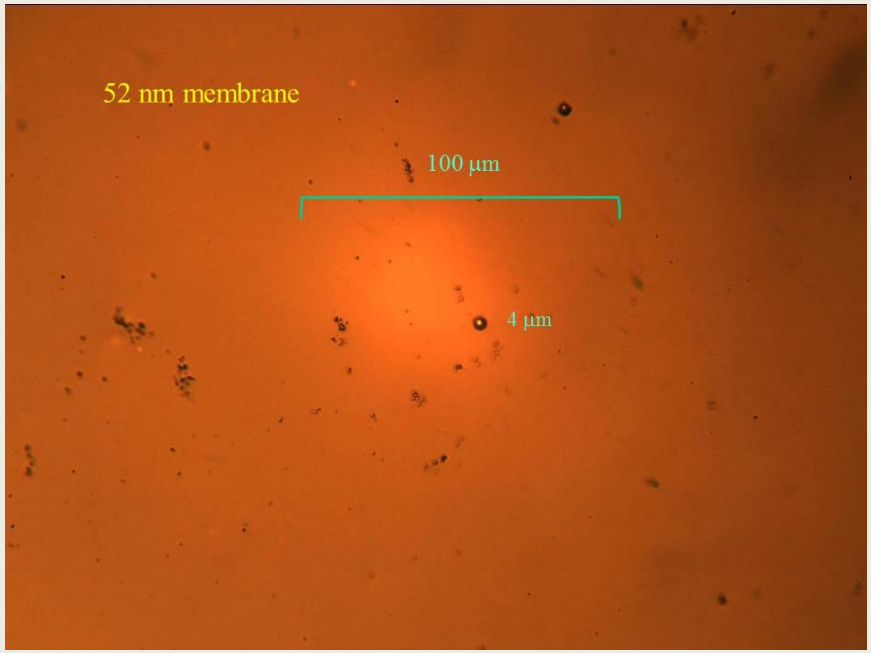
Stopping fast debris particles

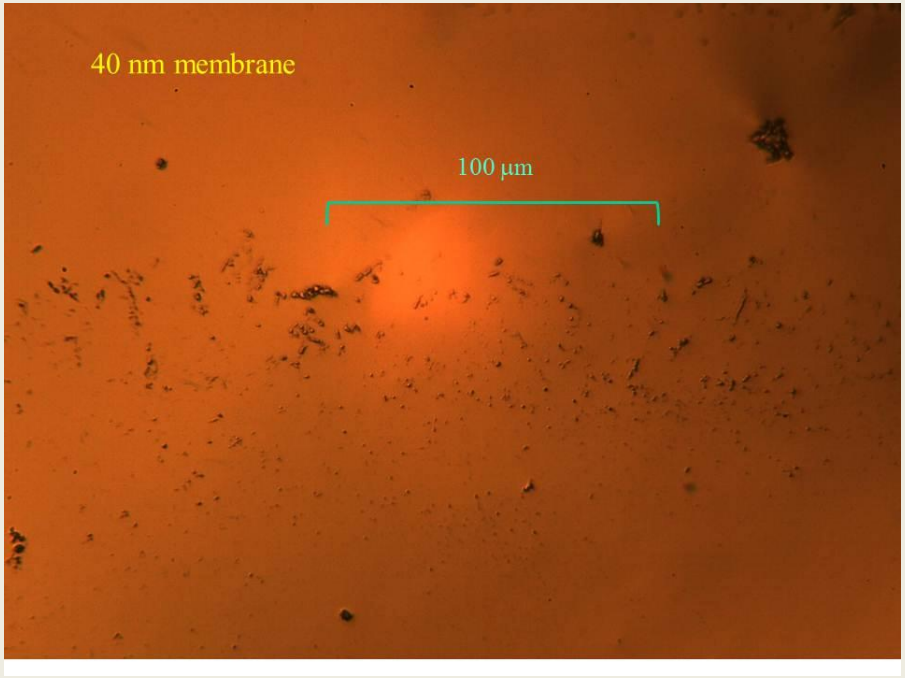
Stopping fast debris particles as valuable additional functionality of SPF membranes has been studied with an LPP source and a particle velocity filter.

It was found that membranes are not punched through by metal particles with sub-micron dimensions and velocities up to 1000 m/s.

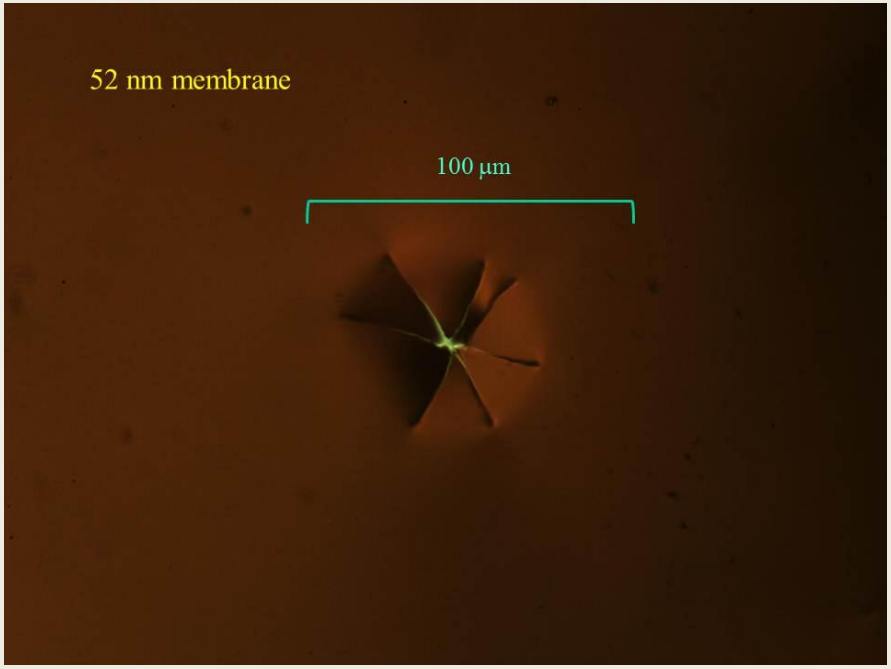


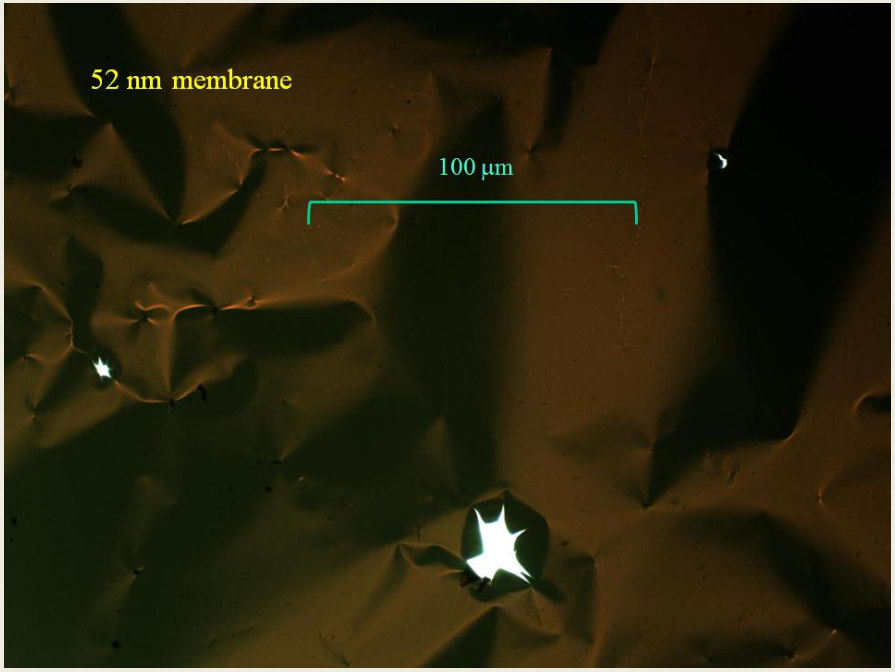
Velocity "edge" filter using honeycomb disc (Ø60×20 mm, cell 3 mm) transmits particles with $V > V_{min}$ without synchronization with LPP





Punch damages by < 2 µm particles have not been found on both 52 nm and 40 nm exposed membranes.
This result is coupled with total number of visible particles (> 0.5 µm) on membrane surface >>1000/mm^2





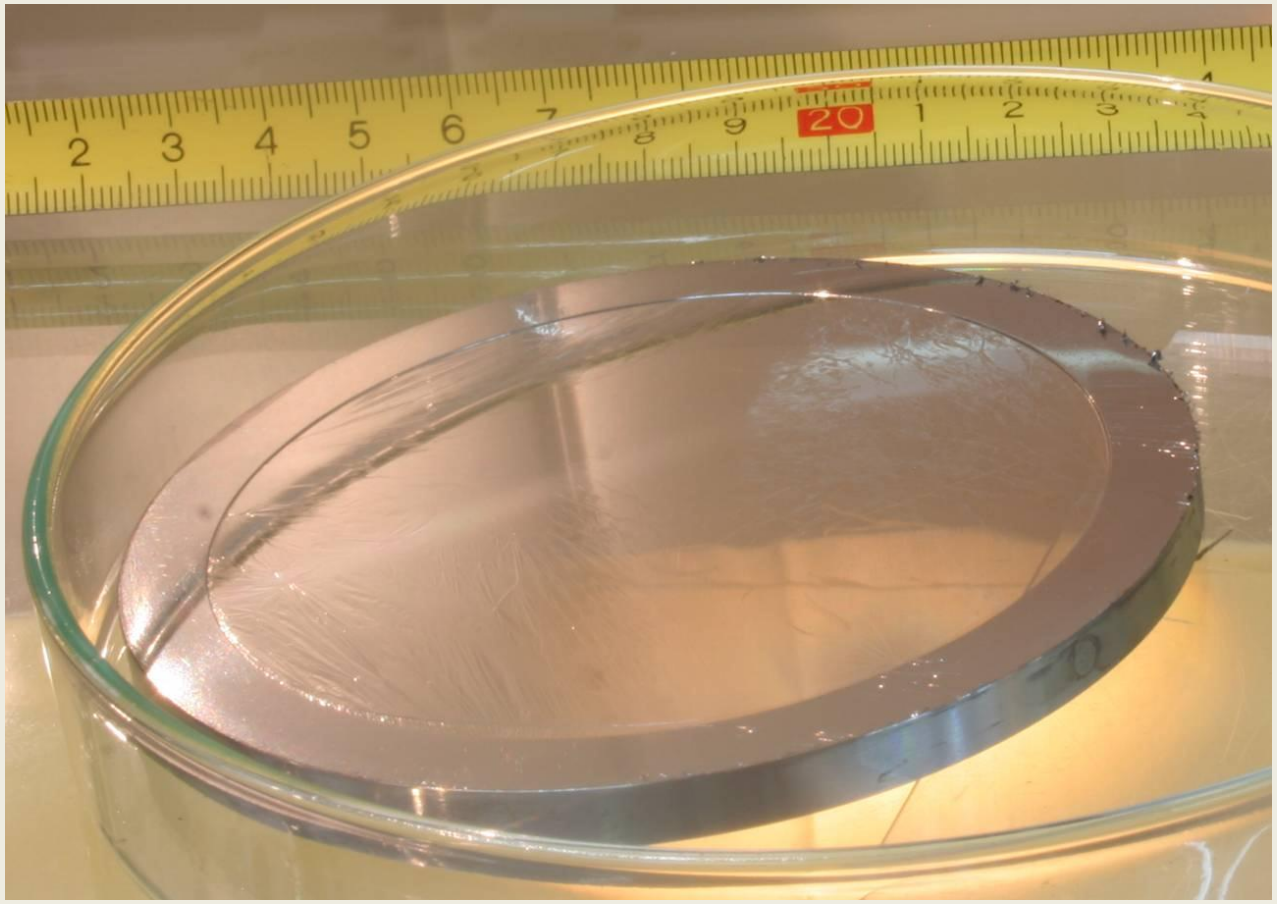
Exposures of 52 nm membranes were arranged to include particles of larger sizes. The low velocity limit was reduced to 300 m/s, laser beam re-focused to generate large target fragments.

Reticle protection by pellicle

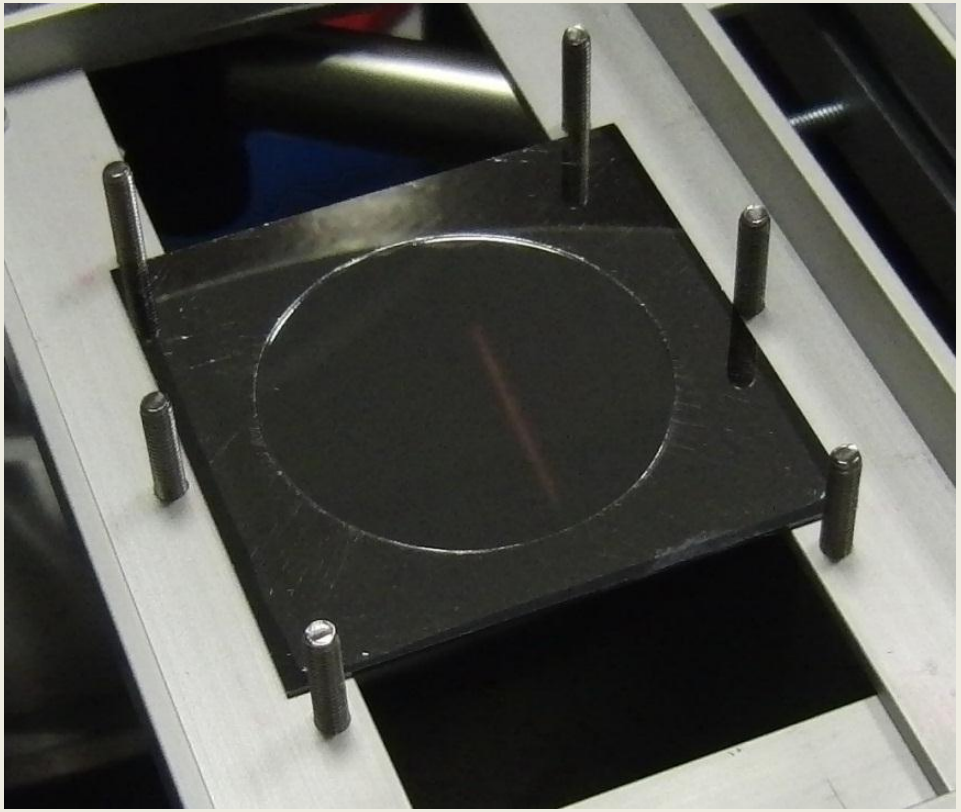
Development of super-thin membranes as pellicles is targeting a two-pass inband transmission above 80%.

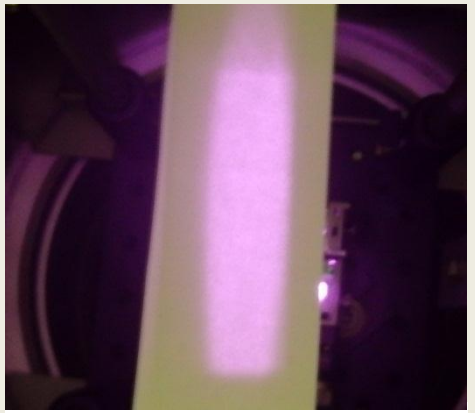
Currently a one-pass transmission of 86% has been demonstrated with 25 nm membranes on 80 mm aperture frames.

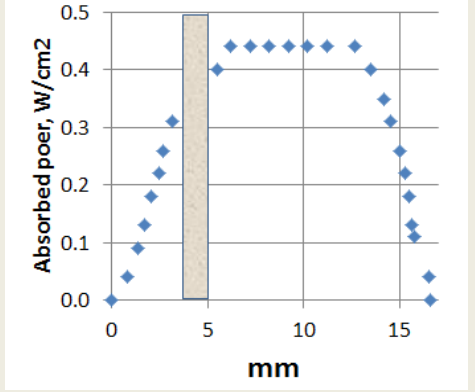
The samples sustained absorbed power loads above 1 W/cm^2 with < 0.1 mm deviations from the initial quasi-stretched surface shape and in-plane acceleration of at least 15 g.



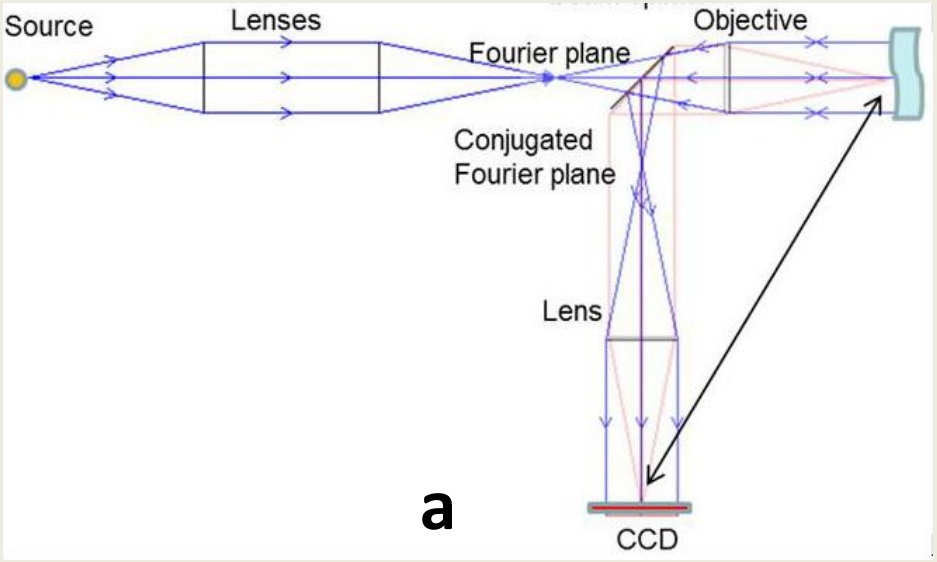
Ultra-thin multilayer membrane on 80 mm aperture frame. Thickness 25 nm, inband transmission 84%







Stretched 25 nm multilayer membrane on 30 mm aperture frame, placed on fast translation stage for tests under specified conditions



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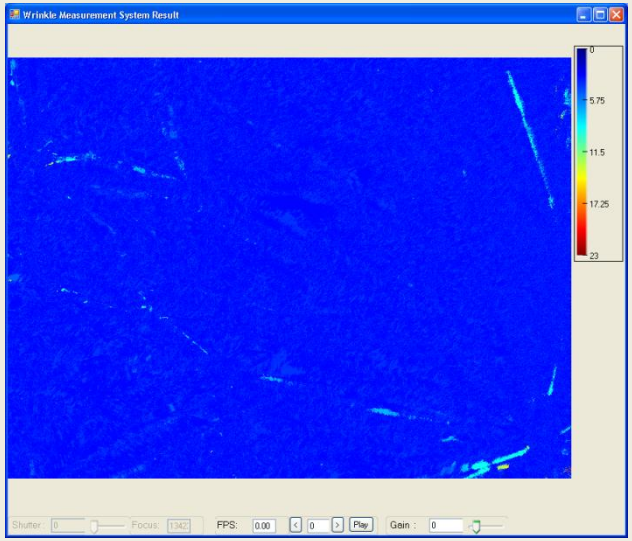

b

a) Optical set-up for surface shape inspection of pellicle membranes to measure deviation angles in wrinkles.

a) Map of maximal wrinkle angles in a 25 nm non-stretched film on a 30 mm aperture frame. Maximal deviation angles are in the range ±2 deg

Conclusion

- Spectral transmission, thermo-mechanical resistance, dimensions and other characteristics enable to consider nanoscale multilayer membranes as potential EUV optical elements for radiation and particle filtration

Priority tasks

- Achievement of higher inband transmission due to technology perfection
- Performance of extensive experimental tests under specified application conditions

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